ADME Fuels

Response to the draft Tasmanian Renewable Hydrogen Action Plan

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24 January 2020

Introduction. This response to the draft Tasmanian Renewable Hydrogen Action Plan (**Hydrogen Plan**) is made in the context of plans by the submitter, ADME Fuels, to build a project to produce renewable hydrogen at the Bell Bay Industrial Precinct in the Australian State of Tasmania, as part of a broader operation at that site where the resulting hydrogen will be reacted with carbon dioxide (**CO_2**) to produce renewable liquid methanol. The project will be known as the Bell Bay Renewable Methanol Project.

The vision behind this project is that Tasmania's uniquely carbon-free electricity can be converted to a simple liquid fuel – liquid electricity – which process will also recycle CO_2 captured from industrial emissions or from the air itself. This vision is part of a growing global awareness that more must be done to reduce the greenhouse gas (**GHG**) profile of fossil fuels used in transportation, industry, mining, agriculture and residential heating. Decarbonising power grids is only part of the story.

Why Hydrogen?

The opening questions in the Hydrogen Plan – Why Hydrogen? and Why now? – in our view, require more detailed explanation. It is much more than just about reacting to the potential emergence of hydrogen export markets.

The overriding objective behind efforts to restructure the global energy system has been to reduce anthropogenic GHG emissions. In Australia at least, concerns such as poor air quality and energy security have failed to drive change to the fossil fuel model, especially for transportation and industry. Even improvements to liquid fuel standards made elsewhere in the world are followed tardily and reluctantly in Australia. Instead, efforts have so far focussed primarily on reducing the use of fossil fuels for the generation of electricity. Given the current carbon-intensity of Australia's power grids, this is a big task.

The numbers[1] tell the story. In 2017-18, Australians consumed 232 TWh[2] of electricity, of which little more than 18% was generated renewably using hydroelectricity and wind and solar power. Nevertheless, this renewable percentage does continue to increase, slowly but surely.

However, reducing fossil fuel GHG emissions in Australia involves an even bigger task – much bigger – than decarbonising the power grids. The monumental challenge facing Australia and the rest of the world is the replacement of fossil fuels used directly for transportation, industry and other non-power generation purposes.

In Australia, the scale of the problem is highlighted by the fact that in 2017-18, in addition to the fossil fuels used for power generation, Australians consumed 629 TWh of diesel, petrol, jet fuel and other refined petroleum fuels, 262 TWh of natural gas and 33 TWh of coal (eg. coal used for steel making), a total of 924 TWh.

In other words, Australia today directly uses *four times* as much fossil fuels in one year as it uses electricity, and that electricity is itself still derived mainly (70 - 80%) from the burning of substantial additional fossil fuels.

It is no wonder then that Australia's fossil fuel GHG emissions continue to rise. Clearly, more action needs to be taken domestically to start replacing refined petroleum liquid fuels (most of which are now imported) and gaseous fuels with greener alternatives, especially given that Australia derives enormous financial benefit from exporting over 4,000 TWh per year of coal and LNG, mostly to Asia.

[1] Extrapolated from Australian Energy Update 2019 (Table 2.8) published by the Australian Department of the Environment and Energy
[2] 1 TWh (terawatt-hour) = 1 billion kWh (kilowatt-hours) or 3.6 billion MJ (megajoules)

The options however are quite limited. It is much more difficult than decarbonising the power grids, hence the negligible progress to date.

Small volumes of biofuels like ethanol and biodiesel are produced domestically, but represent less than 1% of refined liquid fuel usage. Scaling up these volumes will be very challenging, even in Australia with its vast land resources, mainly because of difficult economics, the low energy density of biomass, and sometimes poor energy return on energy invested.

On the other hand, substantial inroads should be possible through the direct electrification of applications that have traditionally been powered by fossil fuels. Replacing conventional passenger cars with electric vehicles, and gas heaters with electric heat pumps, are two examples of how the benefits of decarbonising the power grid could gradually be extended to applications previously reliant on liquid and gaseous fossil fuels. Modern battery development will help facilitate this trend.

And yet, even with electrification, there are physical constraints. Direct electrification alone cannot supply all of the energy needs of a modern economy. Applications currently requiring high energy density fuels such as aircraft, ships, heavy duty trucks, agricultural machinery, and heat-intensive industrial processes are not easily converted to electricity and batteries. Energy in the form of gas and liquids will be required for the foreseeable future. (Indeed, even solid fuels such as coal and wood are likely to continue providing energy for much of the world for decades to come.)

Moreover, fossil fuels are not just a source of energy. They are also the chemical feedstocks for many hydrocarbon-based materials such as fertilisers, plastics and synthetic polymers, upon which the modern world is highly reliant.

Which brings us back to the initial questions – Why hydrogen? and Why now?

First, new technologies and the falling cost of renewable electricity are converging to enable the economic and efficient conversion of electricity to hydrogen via electrolysis of water (**electrolytic hydrogen**). This indirect electrification process offers the prospect of extending the utility of carbon-free electricity (notwithstanding some energy conversion losses along the way) for the replacement of fossil fuels in non-power generating applications. Electrolysis is currently a more costly process for producing hydrogen than the traditional reforming of fossil fuel natural gas, but costs are falling.

There are other methods of generating renewable hydrogen apart from electrolysis, such as the reforming of biogas (instead of natural gas), but electrolysis is not constrained by land or biomass availability, and can be deployed wherever there is electricity. A somewhat controversial alternative has been the proposed gasification of brown coal to hydrogen in the Australian State of Victoria, accompanied by underground sequestration of the resulting CO_2 emissions. While not renewable, this concept offers the possibility (in theory at least) of producing hydrogen cleanly. But the financial, technological and social hurdles are daunting, and in any event, it's a very location-specific solution – hardly the sustainable, longer-term answer that is required at global scale.

Second, as explored in numerous studies and pilot projects, pure hydrogen has the potential to replace natural gas as a cleaner fuel in many instances, and can be the fuel for new applications such as fuel cells, for transportation and other uses. Hydrogen is also a medium for storing and transporting energy in circumstances where direct electrification and batteries are not practical. For various reasons, such as the cost of new electricity transmission, it may be necessary in certain situations to incur the energy losses (about 25%) involved in converting electricity to hydrogen, in order to provide the energy needed to power particular applications.

Finally, renewable hydrogen can be used as an input to reduce the GHG intensity of producing the fuels and chemicals that the modern world presently relies on, such as ammonia, methanol, diesel, petrol, jet fuel and so on. This may well be the most critical role that renewable hydrogen production can play, at least for many years to come. The world needs to begin transitioning away from fossil fuel liquids and gases. If fuels and chemicals are to be made synthetically to reduce their carbon footprint, producing hydrogen is nearly always the starting point. The great advantage of this approach is that there are already large and existing markets and infrastructure for these products.

Why Tasmania?

For the reasons set out in the Hydrogen Plan, Tasmania is ideally placed to play a key part in any transition away from fossil fuel liquids and gases. Its hydroelectricity-based power grid and outstanding wind power resources give it a renewable power profile (95+%) almost unique in the world today. Importantly, Tasmania is also not burdened by some of the political issues faced by most of the other Australian State and the Federal Governments, given that it has –

- no fossil fuel exports;
- no coal-fired power station, or large coal mining communities;
- no natural gas extraction; and
- no oil refineries.

Ironically, these circumstances were once considered to put Tasmania at a disadvantage compared to other parts of the country. Today however, it means that the Tasmanian State Government can promote renewable energy initiatives largely without having to worry about any negative impacts on particular communities or on its own budgetary position.

Establishing a hydrogen market

Although the concept of using hydrogen in its pure form as a fuel and energy carrier has generated enormous interest around the world, the Hydrogen Plan overlooks some of the challenges.

The physical properties of hydrogen mean that the storage, transportation and use of pure hydrogen are all going to require costly new infrastructure and equipment. A very low boiling point (-253˚C) and very low volumetric energy density mean that the storage and transport of useful amounts of pure hydrogen require energy-intensive compression or liquefaction, and expensive materials and tankage. Hydrogen is notoriously 'leaky' – H_2 molecules are small enough to leak through, and embrittle, seals and common metals. Hydrogen is flammable over a wide range of concentrations in air. Advanced engineering and new regulatory regimes will be required to manage safety issues.

So, what is needed to establish a market for pure renewable hydrogen? The near-term prospects will depend on the following factors:

1) The speed of adoption of new applications for pure hydrogen, such as fuel cells, ships, cars, and so on;

2) The development of new technology and infrastructure (such as hydrogen filling stations) to compress/liquefy, store and distribute hydrogen to a much wider range of customers, both domestic and export;

3) Reducing the high cost of the advanced equipment needed for managing the volatility and other challenging physical properties of hydrogen;

4) Developing an effective regulatory regime to ensure the safety of the product;

5) Finding customers who are willing to pay a significant premium for a renewable (as opposed to a natural gas-derived) product for a period of time, even allowing for some assistance from government.

These factors are still the subject of much uncertainty around timing and ultimate scale, with some projections that a viable renewable hydrogen market is still 5 – 10 years away. The pathway, in any event, is very unclear.

On the other hand, producing electrolytic hydrogen for the synthetic production of existing fuels and chemicals is subject to only one major consideration – cost of production. This issue will be considered further below.

Two potential products that could drive the early commercial adoption of electrolytic hydrogen in Australia are ammonia and methanol. Both require hydrogen as a key input in their synthesis. Global annual output of ammonia is currently about 180 million tonnes; for methanol, about 90 million tonnes.

Ammonia is an essential gas in the production of fertilisers and other products such as explosives. It requires care in handling because of its extreme toxicity, but it is already shipped around the world in large volumes without major problems. Due to its very high hydrogen content, it has potential as a hydrogen carrier for markets requiring pure hydrogen.

Methanol as a replacement for fossil fuel oil and gas

However, for the replacement of fossil fuel oil and gas at meaningful scale, the best candidate, in our submission, is methanol – the simplest alcohol. Most people unknowingly consume methanol every day because of very small amounts contained in ripe fruit. Unfortunately, it is also occasionally a source of poisoning because it looks like its chemical cousin, ethanol (both being a clear liquid) and is sometimes unwittingly consumed in dangerous concentrations (even a few millilitres can be unsafe) in the course of backyard distilling of ethanol.

Being the simplest carbonaceous compound (only one carbon atom) that is a liquid at ambient temperate and pressure, methanol is easy to handle and store using existing infrastructure. This feature has far-reaching implications for methanol's potential to replace petroleum fuels, especially when compared to the problems with pure hydrogen gas. Also important is that, unlike other synthetic hydrocarbons, methanol burns very cleanly, and the impacts of spillage are much less polluting.

Methanol has traditionally been used as an intermediate chemical. While Australia no longer produces methanol due to the rising cost of natural gas feedstocks, over 100,000 tonnes is imported each year, mainly (over 70%) for the production of formaldehyde for particle board and other manufacturing processes. Methanol is also an essential ingredient in biodiesel, sewerage treatment processes, and various solvents. More recently, it is being used as an alternative feedstock for ethylene and propylene – the common precursors to modern plastics and polymers that are usually sourced from petroleum or natural gas.

However, it is the growing number of fuel applications for pure methanol that has contributed most to the increase in global consumption. Here are some examples of methanol's versatility as a fuel:

- **Marine fuel.** New international emissions standards for ships have forced ship owners to either install expensive scrubbers, or change to a cleaner fuel. Methanol has been one of the clean fuels chosen by a number of companies to replace dirty-burning bunker oil for their shipping engines. Spillage of methanol is also much less problematic than with petroleum fuels, as it mixes readily with water, and then biodegrades quickly.

- **Conventional vehicles.** China announced in March 2019 that extensive multi-year trials of methanol as an engine fuel for cars, buses and trucks had been successful, and encouraged vehicle manufacturers to expand production. Some cities have up to 10,000 taxis already running on methanol. China is promoting methanol for vehicles to reduce urban air pollution and cut back on the importation of petroleum fuels. It should also be noted that methanol is higher octane and has better performance characteristics than petrol, hence its popularity in the motor sport field.

- **Fuel cells for caravans, boats and other small applications.** Small fuel cells that run directly on methanol are an ideal backup solution for batteries and solar panels in applications like telecommunication towers, or recreational activities such as caravanning and boating. The fuel cell turns on automatically when needed to recharge the battery, and runs quietly without polluting emissions (unlike diesel gensets). As mentioned above, methanol is much more environmentally safe than petroleum fuels.

- **Electric vehicles.** Methanol can be a convenient hydrogen carrier for hydrogen fuel cells, as a way of avoiding expensive high-pressure tanks and refuelling equipment for vehicles. Small onboard reformers convert the methanol to hydrogen for use in a hydrogen fuel cell to charge the battery, at a scale larger than is possible for direct methanol fuel cells. This means being able to use much smaller plug-in batteries to power the electric motors, while at the same time more than doubling the range of the vehicle. Refuelling is then as quick and simple as it is for internal combustion engine vehicles.

- **Power generation.** Both large engines and gas turbines can run on methanol, which is a low-cost (and cleaner) alternative to diesel for off-grid power generation in remote or island locations. Even individual homes not connected to the grid can use methanol fuel cells as a backup for batteries for times when solar panels are not generating enough power.

- **DME production.** Methanol can be converted simply to a gaseous fuel and propellant called dimethyl ether or DME. DME can be an ultra-clean (and potentially carbon-neutral) blendstock for propane in LPG applications like BBQ cylinders and cook tops. It is also a very safe and benign propellant and refrigerant.

While new methanol applications are continually being designed in a number of different countries, it is China which is leading the world in the actual large-scale deployment of methanol as a fuel, thereby demonstrating how petroleum fuels could one day be replaced.

Methanol production

Methanol's versatility as a fuel is almost matched by the versatility of its production. It can be, and is, made from almost any carbonaceous material: wood (the traditional source for many centuries), coal, petroleum, natural gas, municipal solid waste and – of most significance for the future – CO_2.

In particular, new projects are demonstrating a process whereby methanol is produced simply by reacting hydrogen with CO_2 only (ie. without the usual carbon monoxide) under moderate conditions. This involves further energy conversion losses – only 50% of the energy in the electricity used to make the hydrogen and methanol is retained in the methanol itself. However, the end result is a liquid which (unlike pure hydrogen) requires very little further energy to store and distribute. And one litre of that methanol contains 40% more hydrogen (99g) than one litre of liquid hydrogen (71g).

The first semi-commercial CO_2-to-methanol plant in the world was built in Iceland, and has been operating since 2012 using waste CO_2 from a geothermal power station. The methanol plant is named after the late Nobel Laureate Professor George Olah who is credited with conceiving a future energy system – the so-called **Methanol Economy** – where methanol one day replaces oil and gas as the building block for the hydrocarbon fuels and chemicals on which humankind is now so dependent. And this building block could be produced renewably at scale, with water and air supplying the necessary hydrogen and CO_2 respectively, thus making the resulting methanol completely carbon neutral.

In line with Prof Olah's vision, methanol has become one the fastest-growing globally traded commodities, with China alone now consuming over 40 million tonnes per year (about 50% of world production). While China currently produces most of its methanol from coal (elsewhere it is typically made from natural gas), it is positioning itself to transition to renewable production over time, without the need to change the rest of the methanol infrastructure it is presently building.

The commercialisation of new technologies for the direct air capture of the required CO_2 inputs, also predicted by Prof Olah, is now unfolding at a rapid pace, with hundreds of research teams and startup ventures working around the globe, including in Australia. It is only a matter of time before extracting CO_2 from the air will be the most cost-effective means of sourcing the necessary carbon for synthetic production of carbon-neutral methanol. In the meantime, there are numerous industrial processes that can provide the CO_2 required.

Tasmania as a location for 'powerfuel' production

The Chinese Academy of Sciences has referred to methanol sourced from solar electricity as 'liquid sunshine'! In Germany and elsewhere, it is becoming known variously as a 'powerfuel', 'electrofuel' or simply 'e-fuel'. While pure renewable hydrogen will have a future role to play in the transition away from fossil fuel oil and gas, the world can get started today by substituting methanol from electricity – liquid sunshine – wherever petroleum fuels and natural gas can be withdrawn. Indeed, it can be argued that together with the massive expansion of direct electrification of applications, there is no other foreseeable scalable alternative strategy for replacing fossil fuel oil and gas.

To summarise, the benefits to Tasmania of a renewable hydrogen industry which incorporates the co-production of renewable methanol include –

- Tasmania's renewable electricity can be converted to a renewable carbon-neutral liquid fuel which is easy to store and distribute;

- Local production can displace importation of refined petroleum fuels, providing local employment, enhancing energy security, improving urban air quality, reducing risks to the environment, and improving Australia's balance of trade;

- Projects can be built quickly, within a few years, as there is already a large global methanol market in which to sell the output, and new modular plant designs are available for quick construction;

- Tasmania's existing liquid fuel infrastructure – port facilities, stationary tanks, road tankers, etc – can be utilised, with only minor, if any, modifications;

- There is the optionality of being able to supply not only methanol, but also pure hydrogen, DME (for the LPG industry), pure oxygen and pure CO2 from the same plant;

- Innovative technologies such as direct air capture of CO_2 will be deployed and serviced in Tasmania, adding to the local skills base;

- New methanol applications can be introduced to, or even manufactured in Tasmania;

- Opportunities for research projects at local institutions like the University of Tasmania will be expanded;

- Tasmania's 'green' brand can be enhanced, especially for important food export destinations like China.

Action Plan

The actions of the Tasmanian state agencies that would be most effective in incentivising the development of renewable hydrogen-based projects in Tasmania involve reducing production costs to make those projects sustainable, especially –

- Using the levers available via state ownership of Hydro Tasmania and TasNetworks to give developers confidence that they will get access to renewable electricity at prices which will make the production costs of electrolytic hydrogen in Tasmania no higher than other parts of Australia or the world. Electrolytic hydrogen production costs have a dependency on power price comparable to aluminium smelters. Ideally the price mechanism should be sustainable over the typical 20-year life of a project, so that as renewable power prices fall elsewhere, price adjustments can be made for Tasmanian projects.

* Working with the Australian Government to provide assistance with capital for new projects, thereby reducing ongoing debt repayments. This will be necessary to insulate first movers against the falling cost of electrolysers and other equipment that are projected to become cheaper as scale and efficiencies increase over time.

In the case of methanol production, other effective actions could include:

* Guaranteeing the price of renewable methanol output from a plant, similar to the Queensland Government's Solar 150 program for solar farms;

* Providing methanol off-take to fuel government vehicles or government off-grid power generation on island or remote locations;

* Funding the local demonstration of a methanol-fuelled bus (through ownership of Metro Tasmania);

Supporting renewable methanol and ammonia projects will be the quickest and most effective path to establishing a renewable hydrogen industry in Tasmania.

About ADME Fuels

ADME Fuels is an Australian startup proposing to build a series of projects for the renewable production of methanol and DME, from water-derived hydrogen and air-derived carbon dioxide, using renewable electricity.
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